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# Can’t take my eyes off of you

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# CHAPTER 2

## Reward-related attentional biases and adolescent substance use

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# ABSTRACT

Current cognitive-motivational theories of addiction propose that prioritizing appetitive, reward-related information (attentional bias) plays a vital role in the development and maintenance of substance abuse. This study focused on reward-related attentional processes that might be involved in young-adolescent substance use. Participants were young adolescents (N = 682, mean age = 16.14), who completed a motivated game in the format of a spatial orienting task as a behavioral index of appetitive-related attentional processes and a questionnaire to index substance (alcohol, tobacco, and cannabis) use. Correlational analysis showed a positive relationship between substance use and enhanced attentional engagement, with cues that predicted potential reward and non-punishment. These results are consistent with the view that adolescents who show a generally enhanced appetitive bias might be at increased risk for developing heavier substance use.

# INTRODUCTION

Current cognitive-motivational theories of addiction propose that prioritizing appetitive, reward-related information (attentional bias) plays a vital role in the development and maintenance of substance abuse (Field & Cox, 2008; Franken, 2003; Wiers et al., 2007). The selective processing of reward-related information may facilitate detection of substances with desirable (rewarding) consequences. After repeated experiences of the rewarding effects of drug taking, people may end up in a self-reinforcing "attentional bias–craving cycle": attentional bias for drug cues may facilitate the generation of craving, whereas craving may enhance further attentional bias for drug cues, and so forth (e.g., Franken, 2003; Robinson & Berridge, 1993, 2001). In line with this, previous research has found that attentional bias for general reward cues was positively related to alcohol use in students (Colder & O'Connor, 2002) and that people who use or misuse various addictive substances were characterized by an attentional bias for personally relevant substance cues (Field & Cox, 2008; Franken, 2003; Lubman, Peters, Mogg, Bradley, & Deakin, 2000). In addition, high levels of self-reported general reward sensitivity were found to be associated with strong reactivity to alcohol cues among heavy drinkers (Kambouropoulos & Staiger, 2001).

To investigate whether a generally enhanced attentional bias for appetitive information may be involved in early substance (ab)use, the present study was designed to test the relationship between appetitive-related attentional processes and substance use. The use of addictive substances often starts during early adolescence (e.g., Monshouwer et al., 2008), and because it has been shown that the early use of addictive substances is a reliable predictor of later dependence and abuse (Li, Hewitt, & Grant, 2007), the present study focused on early adolescents.

Spatial attention is composed of at least two operative components that might be relevant in the present context: attentional engagement (i.e., facilitated attention toward a cue) and attentional disengagement (i.e., difficulty to disengage attention from a cue; Posner, Inhoff, Friedrich & Cohen, 1987). Both enhanced engagement and enhanced difficulty to disengage attention from reward-relevant cues may independently contribute to the development of substance use and misuse (cf., Koster, Crombez, Verschuere, & De Houwer, 2004). Therefore, we preferred an attentional bias task that can index both types of reward related biases allowing investigating the relative importance of both components of attentional bias. Accordingly, we used a modified Spatial Orienting Task (SOT), as originally designed by Derryberry and Reed (1994, for more details, see Method section). This task was developed to explore to what extent people direct and hold their attention to places where a potential reward is expected, and/or to places where prevention of punishment (i.e., non-punishment) is expected. In terms of Gray's Reinforcement Sensitivity Theory, the Behavioral Approach System (BAS) is responsible for organizing behavior in response to appetitive stimuli, which signals both unconditioned reward and the relief from punishment (non-punishment; Gray, 1970, 1982). There is ample evidence that substance abuse disorders are related to high self-reported BAS-sensitivity, which motivates behaviors that are intended to attain rewards (or non-punishment), with little attention for the possibilities of negative consequences (i.e., nonreward or punishment; see for review, Bijttebier, Beck, Claes, & Vandereycken, 2009). Attentional biases as indexed by the SOT have been linked to reward- and punishment-related processes, suggesting that this task is useful for assessing biases in processing positive and negative incentives (Colder & O'Connor, 2002; Derryberry & Reed, 2002; Pratt, 2008). Therefore, the SOT provides the welcome opportunity to investigate attentional responses to both expected reward and non-punishment, and thus, to examine to what extent individual differences in both of these aspects of BAS are involved in substance use.

During the present SOT, participants respond to a simple target appearing on the left or the right side of a fixation cross by pressing a single response button. Their score after responding depends on their speed in detecting the target. The target is preceded by a peripheral cue that acts as a signal and appears left or right of the fixation cross. That is, the cue (i.e., a blue arrow pointing upward or a red arrow pointing downward) predicts whether a target at that location would result in a probable positive or negative outcome. Specifically, a blue arrow predicts higher chance at a positive outcome (either reward or non-punishment), if the target appears at the location cued by the blue arrow, whereas a red arrow predicts higher chance at a negative outcome (either nonreward or punishment), if the target appears on the location cued by the red arrow (for more detail, see Method section). It is important to note that this task consists of two different games: a positive game in which a positive outcome is a 10 point gain, and a negative outcome a null-gain, on the one hand, and a negative game in which a positive outcome is a null-loss, and a negative outcome a 10-point loss, on the other. Thus, the positive games (blocks of trials) result in a positive (or null) score and the negative games in a negative (or null) score. It is proposed that the cues in the positive games elicit states related to potential reward (i.e., blue arrow cues) and frustrative nonreward (i.e., red arrow cues), and the cues in the negative games signal potential safety/non-punishment (i.e., blue arrow cues) and punishment (i.e., red arrow cues). Because the cues are designed to be predictive for the outcomes, a person's motivation for reward or non-punishment are inferred from attention toward or away from the presented cues. Thus, this task allows influence of more strategic or voluntary control. The posterior attentional system is assumed to be a relatively reactive (involuntary) system that focuses the attentional "spotlight" to a particular location. During subsequent stages of attentional processing, the anterior system gets into action, which is generally viewed as an executive system that serves the more voluntary functions and regulates the posterior orienting system (for more details, see Derryberry & Reed, 2002). To examine the relative importance of more automatic and more voluntarily attentional processes in the alleged relationship between attention bias for reward and substance use, we included two different cue presentation times (250 ms and 500 ms) in the present SOT, which were successfully used to demonstrate differences in attentional biases for threat and safety in anxious people (Derryberry & Reed, 2002). It is important to note that using two different presentation times allowed testing whether the hypothesized relationship between substance use and attentional biases for appetitive stimuli would be especially pronounced under conditions that allow, or under conditions that preclude, a regulatory influence on participants' appetitive bias. Thus, the present approach enabled us to examine whether substance use is predominantly associated with relatively strong involuntary (automatic) attentional processes, with relatively strong regulatory (effortful) processes, or both.

In short, the present study investigated the relationship between appetitive attentional processes and adolescent substance use. According to cognitive motivational models of addiction, heightened attentional bias to appetitive cues will be related to high levels of substance use. We therefore hypothesized that an attentional bias toward cues of reward and non-punishment would be associated with high levels of substance use. We expected this bias to emerge as (a) an enhanced engagement toward and (b) a reduced disengagement from cues of reward and non-punishment. Furthermore, we explored whether this relationship is especially strong when there was little or when there was much time to voluntarily control attentional processes. The current study used a behavioral measure to examine the role of BAS sensitivity in substance use, complementing previous work that (a) investigated BAS sensitivity in addiction with self-report measures and (b) examined attentional biases toward specific addiction-relevant items (e.g., beer, wine, cigarettes). Furthermore, this study focused on young adolescents instead of adults. Therefore, this study provides a unique opportunity to behaviorally test the role of appetitive attentional bias in the initiation stage of substance use and may give clues for preventing the development of substance use problems.

# METHOD

## *Participants and Recruitment*

Participants were a subsample of Tracking Adolescents' Individual Lives Survey (TRAILS), a large prospective population study of Dutch adolescents with bi- or triennial measurements from age 11 to at least age 25. This cohort of 2,230 adolescents (baseline: mean age = 11.09 years, *SD* = 0.56, 50.8% female, response rate = 76%) was recruited via primary schools in five northern municipalities (including urban and rural areas) and constituted 64% of all children born between October 1989 and September 1990 (first three municipalities) or October 1990 and September 1991 (last two municipalities) in these areas (for more details, see Huisman et al., 2008; de Winter et al., 2005). The present study reports data from the third (T3) assessment wave that ran from September 2005 to December 2007, in which 1,816 (81% of initial sample) adolescents participated. Because all participants were recruited from the same school grade, the age range was relatively narrow (i.e., mean age = 16.3, range = 14.7–18.7). For reasons of feasibility and costs, a focus cohort of 744 adolescents was invited to perform a series of laboratory tasks on top of the usual assessments, of whom 715 (96%) agreed to participate. Adolescents with a high risk of mental health problems had a greater chance of being selected for the experimental session. High risk was defined based on temperament (high frustration and fearfulness, low effortful control), lifetime parental psychopathology (depression, anxiety, addiction, antisocial behavior, psychoses), and living in a single-parent family. In total, 66% of the focus cohort had at least one of these risk factors. The remaining 34% were randomly selected from the low-risk TRAILS participants. Hence, the focus cohort still represented the whole range of problems seen in a normal population of adolescents, which made it possible to represent the distribution in the total TRAILS sample by means of sampling weights (for more detailed information on the selection procedure and response rates within each stratum, see Appendix 2A). The present study included only participants who completed both the Spatial Orienting Task and the Substance Use Questionnaire (SUQ). Two participants were excluded because of incomplete SOT data and one participant for making over 25% errors on the SOT. Twenty-seven participants were excluded for having more than three missing SUQ item scores, and three because of extreme outlier scores (N = 682).[1] Descriptive statistics of the final sample (weighted estimates) are presented in Table 2.1.[2]

**Table 2.1**

*Sample Characteristics (N = 683 [a])*

| Variable | Mean (SD) or percentage |
|---|---|
| Female Gender | 51.3% |
| Age | 16.14 (0.60) |
| Servings of alcohol/week over previous month [b] | 6.00 (7.24) |
| Cigarettes/day over previous month | 2.22 (4.71) |
| Frequency of cannabis use over previous month | 0.75 (2.47) |
| Lifetime Abstainer of alcohol, tobacco and drugs | 9.9% |

*Note.* SD = standard deviation; [a] The sample size reported reflects the weighted sample size; [b] One serving of alcohol contains approximately 11 ml of pure alcohol.

## *Procedure*

**Laboratory behavioral assessment.** As an index of attentional bias for appetitive stimuli we used the SOT (Derryberry & Reed, 2002). The SOT was the first computer task of a larger set of experimental tests. The experimental protocol was approved by the Central Committee on Research Involving Human Subjects (CCMO). The test assistants received extensive training to optimize standardization of the experimental session. Participants were tested on weekdays, in a sound-attenuating room with blinded windows at selected locations in the participants' town of residence.

*Spatial Orienting Task.* The task was presented on a Philips Brilliance 190 P monitor controlled by an Intel Pentium 4 CPU computer using E-prime software version 1.1 (Psychology Software Tools Inc, Pittsburgh, Pennsylvania). Participants were seated 50 cm away from the screen, and responses were collected on the computer's keyboard.

[1] Because the missing participants were only a 5% of the total group, there are no strong indications that these few differences could have influenced the data. To be sure, we imputed the data set, and reanalyzed the data, which resulted in the same conclusions.

[2] As a result of the exclusion of 33 participants, who carried different weights, the use of this weighting procedure resulted in a deviant final weighted sample size of 683.

**Table 2.2**
*Description of scores in the positive and negative games*

| Game | Target trials | | Catch trials | |
|---|---|---|---|---|
| | RT<cut-off (fast enough) | RT>=cut-off (too slow) | No response (accurate) | Response (inaccurate) |
| Positive | + 10 points | 0 points | 0 points | - 10 points |
| Negative | 0 points | - 10 points | 0 points | - 10 points |

*Note.* RT = reaction time.

**Table 2.3**
*Overview of trial types; anticipated outcomes of targets following easy or hard cues and the calculation of exact cut-off times (in ms) for response time-interval*

| SOT – trials | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cue | Delay | Odds | Target | Signal | Relative time to respond | Exact cut-off time to respond | Anticipated outcome |
| Easy (blue) | 250ms | 2/3 | Cued | Easy | Much | mRT+0.55SD+12 ms | 75% chance of a positive outcome |
| | | 1/3 | Uncued | Hard | Little | mRT-0.55SD+12ms | 75% chance of a negative outcome |
| Easy (blue) | 500ms | 2/3 | Cued | Easy | Much | mRT+0.55SD-12ms | 75% chance of a positive outcome |
| | | 1/3 | Uncued | Hard | Little | mRT-0.55SD-12ms | 75% chance of a negative outcome |
| Hard (red) | 250ms | 2/3 | Cued | Hard | Little | mRT-0.55SD+12ms | 75% chance of a negative outcome |
| | | 1/3 | Uncued | Easy | Much | mRT+0.55SD+12ms | 75% chance of a positive outcome |
| Hard (red) | 500ms | 2/3 | Cued | Hard | Little | mRT-0.55SD-12ms | 75% chance of a negative outcome |
| | | 1/3 | Uncued | Easy | Much | mRT+0.55SD-12ms | 75% chance of a positive outcome |

*Note.* SOT = Spatial Orienting Task; m = median; RT = reaction time; SD = standard deviation.

*Task description.* In collaboration with Derryberry and Reed, we programmed an SOT that was virtually identical to their original task (SOT; Derryberry & Reed, 2002). The task consisted of four positive and four negative blocks of trials (games), which alternated in sets of two, starting with two positive games (see Tables 2.2 and 2.3 and Appendix 2B). On positive blocks, participants gained 10 points for fast responses, and did not gain points for slow responses (definitions of fast and slow are given below). Thus, positive blocks allow for the assessment of approach toward reward. On negative blocks, participants lost 10 points for slow responses and did not lose points for fast responses. Thus, negative blocks allow for the assessment of approach toward non-punishment. Regardless of the block, 10 points were lost for inaccurate responses. The score was reset to zero at the start of each game. Participants were informed that those with the highest scores in the positive games would win an attractive prize (e.g., a balloon ride), while extremely low scores in the negative games could result in having to do the task again, until performance would be good enough.

*Stimuli.* Throughout each game, two vertical black bars were displayed against a white background, which marked the location of the cues and targets (for a schematic overview of trial structure, see Appendix 2C). Participants were instructed to fixate on the score, which was presented in black at the screen's center. The score was updated after each response (see below) and remained on the screen throughout the trial. Each trial began with turning the fixation score off for 200 ms and then back on for 250 ms. Next, a cue arrow replaced one of the two vertical black bars. After a delay of 250 or 500 ms, a target appeared. The target was a small vertical gray rectangle centered within the cue arrow (cued target) or within the vertical black bar on the opposite side of the fixation score (uncued target; see Appendix 2D). Participants were told that a blue up-arrow (easy cue) signaled that a target appearing in that location (cued) would be “easy” (i.e., own mean reaction time (RT) + 0.55 SD to react) and result in a sufficiently fast response about 75% of the time, whereas a target in the uncued bar's position would be “hard” (i.e., own mean RT – 0.55 SD to react); that is, resulting in a too slow response about 75% of the time. A red down-arrow (hard cue) indicated that a cued target would be “hard” (the response would be too slow 75% of the time) and an uncued target “easy” (the response would be sufficiently fast 75% of the time). In addition, they were informed that the cue would also indicate the probable location of the target, with 2/3 of the targets appearing in the cued location, and that occasionally no target would appear (catch trials). Participants were instructed to press the ‘b’ key as soon as they detected the target. Pressing the key before the target appeared or when no target appeared resulted in a loss of 10 points. Each block consisted of 32 cued, 16 uncued, and 8 catch trials, in random order. A total of 500 ms after the response (or 1 s following the delay interval on catch trials), the cue arrow and target were removed by reinstating the two black bars, and a feedback signal was presented below the central score. Feedback consisted of the same arrows as used for the cues. A blue up-arrow indicated a fast response or (accurate) nonresponse on catch trials. A red down-arrow signaled a slow response or (inappropriate) response on catch trials. After a delay of 250 ms, the score was updated (if changed). After a randomly selected inter-trial interval of 500 or 1000 ms, the next trial began by removing the feedback signal and blanking the score for 200 ms.

*Feedback computation.* At the end of each game, the participant's median RT and standard deviation were computed to calculate cutoffs for fast and slow responses on the next game of the same type (positive or negative; see also Tables 2.2 and 2.3). Consistent with the previous work of Derryberry and Reed, for easy targets, the response was labeled as fast if the RT was less than the median plus 0.55 times the SD. For hard targets, a response was treated as fast if the RT was less than the median minus 0.55 times the SD. If RTs equaled or exceeded these cutoffs, they were treated as slow. Because RTs tend to be about 25 ms slower after short delays, 12 ms were added to the cut-off for short-delay trials and subtracted for long-delay targets (see Appendix 2E; for more detailed task description, see also Derryberry & Reed, 2002). Because the response window was adapted online on the basis of the participant's individual performance, there were no participants with extremely low scores.

*Self-reported substance use.* Measures of alcohol, tobacco, and cannabis use were part of a larger self-report survey, which was completed at school, supervised by test assistants (see Huizink, Ferdinand, Ormel, & Verhulst, 2006). Noncannabis illicit drug use (e.g., amphetamines, cocaine, XTC) was left out of the analyses because only 21 participants (4%) indicated having used these drugs. Substance use was calculated on quantity and frequency items of alcohol use (nine items), tobacco use (four items), and cannabis use (three items, see Appendix 2F). Because of their different scaling, standardized scores were used to calculate measures for alcohol (Cronbach's alpha = .85), tobacco (Cronbach's alpha = .84), and cannabis use (Cronbach's alpha = .90). Finally, as an index of general substance use, we used the means of these alcohol, tobacco and cannabis measures to calculate a substance use measure (Cronbach's alpha = .70). This measure was skewed and to normalize the distribution a square root transformation was carried out.

## *Data Reduction and Analysis*

The SOT RT data were analyzed following Derryberry and Reed (2002). First, RTs below 125 ms (probable anticipations) and above 1,000 ms (probable distractions) were removed. The mean percentage of outliers was 5%. Mean RT for each condition was calculated after removing outlier trials.

Participants generally respond faster to cues that appear in regions of a visual display to which they are attending than to cues in regions to which they are not attending (Posner et al., 1987). Therefore, attentional engagement toward expected reward (positive games) or non-punishment (negative games) is inferred when participants respond faster to cued targets preceded by easy (blue) cues than to those preceded by hard (red) cues. Difficulty to disengage attention from expected reward (positive games) or non-punishment (negative games) is inferred when participants respond slower to uncued targets preceded by easy (blue) cues than to those preceded by hard (red) cues (e.g., Koster et al., 2004).

**Table 2.4**
*Calculation of approach toward reward scores*

| Type of game | Positive games: approach toward reward | | | |
|---|---|---|---|---|
| Type of trial | Short-delay trials (250 ms) | | Long-delay trials (500 ms) | |
| Attentional bias scores | Engagement towards expected gain | Difficulty to disengage from expected gain | Engagement towards expected gain | Difficulty to disengage from expected gain |
| Formula's | RT cued red trials minus RT cued blue trials | RT uncued blue trials minus RT uncued red trials | RT cued red trials minus RT cued blue trials | RT uncued blue trials minus RT uncued red trials |

*Note.* RT = reaction time.

**Table 2.5**
*Calculation of approach toward non-punishment scores*

| Type of game | Negative games: approach toward non-punishment | | | |
|---|---|---|---|---|
| Type of trial | Short-delay trials (250 ms) | | Long-delay trials (500 ms) | |
| Attentional bias scores | Engagement towards expected non-loss | Difficulty to disengage from expected non-loss | Engagement towards expected non-loss | Difficulty to disengage from expected non-loss |
| Formula's | RT cued red trials minus RT cued blue trials | RT uncued blue trials minus RT uncued red trials | RT cued red trials minus RT cued blue trials | RT uncued blue trials minus RT uncued red trials |

*Note.* RT = reaction time.

Accordingly, we computed the engagement and disengagement scores (see Tables 2.4 and 2.5). Hence, attentional bias for reward was represented in the positive games as both (a) a relatively faster engagement toward cues of expected gain (blue arrow acting as correct cue for target; cued blue trials) than cues of expected nongain (red arrows acting as correct cue for target; cued red trials) and (b) slower disengagement from expected gain (blue arrow acting as incorrect cue for target; uncued blue trials) than expected nongain (red arrows acting as incorrect cue for target; uncued red trials). Analogously, attentional bias for non-punishment was represented in the negative games, by both (a) a relatively faster engagement toward cues of expected nonloss (blue arrows acting as correct cue for target; cued blue trials) than cues of expected loss (red arrows acting as correct cue for target; cued red trials) and (b) slower disengagement from expected nonloss (blue arrow acting as incorrect cue for target; uncued blue trials) than expected loss (red arrows acting as incorrect cue for target; uncued red trials). All scores were separately calculated for short-delay and long-delay trials (i.e., when there was less or more time to voluntary control the attention).

**Table 2.6**

*Mean score reaction times (M in ms) and standard deviations (SD) of SOT scores (N = 683 [a])*

| Type of game | Short Delay | | | | Long Delay | | | |
|---|---|---|---|---|---|---|---|---|
| | Cued | | Uncued | | Cued | | Uncued | |
| | Easy | Hard | Easy | Hard | Easy | Hard | Easy | Hard |
| | M(SD) | M(SD) | M(SD) | M(SD) | M(SD) | M(SD) | M(SD) | M(SD) |
| Positive | 335(42) | 366(47) | 467(89) | 469(88) | 341(57) | 378(66) | 382(75) | 376(73) |
| Negative | 328(46) | 356(52) | 453(88) | 456(92) | 331(58) | 365(68) | 379(81) | 373(76) |

*Note.* SOT = Spatial Orienting Task; [a] The sample size reported reflects the weighted sample size.

## RESULTS

### *Reaction time data*

RT data are shown in Table 2.6. First, we examined whether general task performance was in line with the design of the task. Therefore, we carried out a series of paired samples t tests comparing participants' performance during uncued versus cued trials for all relevant types of trials (Table 2.7). These tests showed an overall engagement effect (i.e., participants were generally faster at cued easy trials than at cued hard trials; mean difference cued hard-cued easy = 32 ms, t = 31.46, $p < .001$, Cohen's $d = 1.25$), and a disengagement effect only for long-delay trials (i.e., in 500 ms games, participants were faster at uncued hard trials than at uncued easy trials, mean difference = 6 ms, $t = 4.05$, $p < .001$, Cohen's $d = 0.16$). Attesting to the validity of the present approach, participants generally showed a preference for directing their attention toward cues of reward or non-punishment (easy [blue] cues) compared with cues of frustrative nonreward or punishment (hard [red] cues) and that this effect occurred both when the conditions supported automatic (250-ms delay condition) and voluntary (500-ms delay condition) attentional processes. In addition, participants demonstrated more difficulty in disengaging attention from cues of reward or non-punishment (easy [blue] cues) compared with cues of frustrative nonreward or punishment (hard [red] cues), but only when they had more time to voluntarily control their attention (500-ms delay condition).

**Table 2.7**

*Paired-samples t-tests testing the differences in reaction times between hard and easy trials of the Spatial Orienting Task (SOT), separated between type of trials (cued vs. uncued, short-delay vs. long-delay and positive vs. negative game); as measures for engagement and disengagement effects (N = 683 [a])*

| Type of trial | | | Mean | t | Cohens *d* | Df |
|---|---|---|---|---|---|---|
| Positive games | S-D | Attentional engagement to reward (ch – ce) | 30.65 | 24.97** | 0.97 | 682 |
| | | Difficulty to disengage from reward (ue – uh) | -2.70 | -1.13 | -0.04 | 682 |
| | L-D | Attentional engagement to reward (ch – ce) | 36.23 | 19.36** | 0.75 | 682 |
| | | Difficulty to disengage from reward (ue – uh) | 5.76 | 2.85** | 0.11 | 682 |
| Negative games | S-D | Attentional engagement to non-punishment (ch – ce) | 27.91 | 20.92** | 0.81 | 682 |
| | | Difficulty to disengage from non-punishment (ue – uh) | -2.53 | -1.01 | -0.04 | 682 |
| | L-D | Attentional engagement to non-punishment (ch – ce) | 33.91 | 17.24** | 0.67 | 682 |
| | | Difficulty to disengage from non-punishment (ue – uh) | 6.81 | 3.00** | 0.12 | 682 |

*Note.* S-D = short-delay; L-D = long-delay; ce = cued easy; ch = cued hard; ue = uncued easy; uh = uncued hard; [a] The sample size reported reflects the weighted sample size; ** $p < 0.01$ (two tailed).

## *Reward-Related and Punishment-Related Attentional Biases and Substance Use*

To investigate the relationship between substance use and attentional biases, we first performed a bivariate correlational analysis. Table 2.8 shows that substance use correlates with age and with engagement toward both reward and non-punishment for both short-delay and long-delay trials. There were no significant correlations between substance use and gender, or the disengagement from either reward or non-punishment scores.

**Table 2.8**

*Bivariate correlations of attentional bias scores and substance use (N = 683 [a])*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Substance use [b] | - | | | | | | | | | | |
| 2 | Gender | .06 | - | | | | | | | | | |
| 3 | Age | .12** | -.03 | - | | | | | | | | |
| 4 | Attentional engagement toward reward (S-D) | .08* | .02 | -.05 | - | | | | | | | |
| 5 | Difficulty disengaging from reward (S-D) | -.02 | -.08* | -.01 | -.05 | - | | | | | | |
| 6 | Attentional engagement toward non-punishment (S-D) | .11** | .01 | -.02 | .29** | -.05 | - | | | | | |
| 7 | Difficulty disengaging from non-punishment (S-D) | .02 | .06 | .01 | .02 | .04 | -.08* | - | | | | |
| 8 | Attentional engagement toward reward (L-D) | .12** | .01 | -.01 | .22** | -.01 | .12** | -.06 | - | | | |
| 9 | Difficulty disengaging from reward (L-D) | -.03 | -.01 | -.01 | -.05 | .01 | -.08* | -.00 | .01 | - | | |
| 10 | Attentional engagement toward non-punishment (L-D) | .09* | .00 | -.05 | .22** | .04 | .20** | .05 | .20** | -.05 | - | |
| 11 | Difficulty disengaging from non-punishment (L-D) | -.05 | -.01 | -.03 | .00 | .02 | -.06 | -.00 | -.07 | .05 | -.03 | - |

*Note.* S-D = short-delay; L-D = long-delay; [a] The sample size reported reflects the weighted sample size; [b] Substance use was square root transformed before analysis; * $p < 0.05$; ** $p < 0.01$.

## *Bivariate Correlations of Attentional Bias Scores and Substance Use*

We carried out a hierarchical regression analysis to test the unique contribution of each of the attentional engagement scores in predicting substance use. Step 1 included age, and Step 2 included attentional engagement to reward (both short and long-delay blocks) and attentional engagement to non-punishment (both short and long-delay blocks. Gender and disengagement variables were left out of analysis, as there were no indications that these variables contributed to the prediction of substance use. The alpha level was set to 0.05. This full model explained 4% ($R^2$ adjusted = 0.04), $F(5, 677) = 6.09$, $p < .001$, of all variance. The model showed that age, attentional engagement toward non-punishment (short delay), and attentional engagement toward reward (long delay) all predicted unique variance of substance use (Table 2.9).[3]

**Table 2.9**

*Hierarchical regression model for variables explaining substance use [a] (N = 683 [b])*

| Variable | | B | t | $R^2$ Change |
|---|---|---|---|---|
| Step 1 | | | | |
| | (Constant) | | 55.36** | |
| | Age | 0.12 | 3.19** | 0.02 |
| Step 2 | | | | |
| | (Constant) | | 55.29** | |
| | Age | 0.13 | 3.41* | |
| | Attentional engagement toward reward (short-delay) | 0.03 | 0.67 | |
| | Attentional engagement toward non-punishment (short-delay) | 0.09 | 2.20* | |
| | Attentional engagement toward reward (long-delay) | 0.09 | 2.31* | |
| | Attentional engagement toward non-punishment (long-delay) | 0.05 | 1.40 | 0.03 |

*Note.* $R^2$ final model = 0.04**; Adjusted $R^2$ = 0.04; [a] substance use was square root transformed before analysis; [b] the sample size reported reflects the weighted sample size; * p < 0.05; ** p < 0.01.

## DISCUSSION

The present study was designed to explore whether attentional biases for general appetitive cues (of reward and non-punishment) might be related to substance use in early adolescence. This study tested the relationship between the strength of attentional biases and substance use behavior in a large representative cohort of young adolescents. The main results can be summarized as follows: First,

[3] Regression analysis was repeated for the square root transformations of alcohol use, tobacco use and cannabis use separately, which showed that there was an effect for attentional engagement toward reward (long delay) in the prediction of alcohol ($p$ = .03), and cannabis use ($p$ = .05), but not for tobacco use. Attentional engagement toward non-punishment (short-delay) predicted tobacco use ($p$ = .02), but not alcohol or cannabis use. Note that the variable of cannabis use was highly skewed (i.e., >2).

substance use was related to attentional bias for appetitive cues. Hierarchical analyses indicated that of the four measures of attentional biases which demonstrated bivariate correlations with substance use, attentional engagement toward non-punishment in the 250-ms delay condition and attentional engagement toward reward in the 500-ms delay condition both predicted unique variance of substance use. Second, independent of their substance use score, adolescents showed an enhanced engagement toward both reward and non-punishment in both short-delay and long-delay trials. Furthermore, they showed a difficulty to disengage their attention from reward and non-punishment during long-delay trials.

The finding that, overall, adolescents showed an attentional bias for reward and non-punishment is in line with previous reports indicating that adolescence is characterized by an enhanced sensitivity to appetitive stimuli (e.g., Spear & Varlinskaya, 2010; Van Leijenhorst et al., 2010) and attested to the validity of the task. Most important in the present context, the use of this particular behavioral paradigm provided additional clues regarding the nature of substance-related attentional biases concerning reward and non-punishment. The results suggest that the crucial substance-related attentional biases involve enhanced engagement with cues of reward and non-punishment rather than with problems disengaging from cues of reward and non-punishment. That is, attention is attracted and held more strongly to cues predicting reward compared with cues predicting frustrative nonreward, and to cues predicting non-punishment compared with cues predicting punishment. This correlational pattern was apparent for both short-delay trials, which reflect the relatively automatic processes, and long-delay trials, in which there is more opportunity to voluntary control attention. Regression analyses indicated that relatively strong automatic engagement toward non-punishment and relatively strong voluntary engagement toward reward have unique value in the explanation of substance use. Thus, the predictive value of the various engagement scores are not entirely redundant and the more automatic and the more controlled attentional engagement scores showed at least partly complementary predictive value. A possible explanation for this pattern could be that a strong automatic engagement toward non-punishment relative to engagement toward punishment reflects weak automatic fear of negative consequences (e.g., fear of getting a hang-over), and a strong voluntary engagement toward reward represents a heightened voluntary drive to receive rewards (e.g., attaining pleasant feelings after drug use). Obviously, before making any strong conclusions, these results have to be replicated and tested subsequently.

The general pattern of results is consistent with research showing strong self-reported BAS sensitivity (i.e., sensitivity to stimuli that signal reward and non-punishment) to be associated with substance use (see for review, Bijttebier et al., 2009). Moreover, these results replicate and add to the central findings of other researchers, that high BAS sensitivity is associated to adolescent and adult substance use (e.g., Franken, 2002; Genovese & Wallace, 2007; Johnson, Turner & Iwata, 2003; Knyazev, 2004). Furthermore, finding this relationship in a young adolescent sample lends support to the idea that this appetitive bias might be an important factor in the initiation of adolescent substance use. That is, this facilitated attention toward appetitive cues may lead to a more detailed and sustained processing of the positive effects of substance use, and may increase the likelihood that the association between cues and positive (desired) effects of substance use will be stored in memory. This may lead to an increase in arousal and an enhanced attentional bias for substance cues, which both may lower the threshold for eliciting craving and approach tendencies, which may eventually lead to an increase in use. Accordingly, (young) adolescents who show heightened attentional bias toward appetitive stimuli might therefore be at risk for initiating substance use at a younger age and subsequently for developing substance use problems.

However, it is important to note that the cross-sectional design of our study does not allow any firm conclusion regarding the direction of the relationship between attentional bias and substance use. Therefore, it is important to test the proposed interrelationship in a longitudinal design. This would give the opportunity to investigate not only whether there is a correlation between attentional bias and adolescent substance use, but also whether attentional bias precedes abuse, and thus has predictive value for future substance abuse. Furthermore, combining this SOT with a measure that assesses substance-related attentional bias (e.g., a Visual Probe Task) might provide supplementary information about the proposed relationship between the more general reward-related attentional processes and the more stimulus-specific attentional bias for personally relevant substances.

Finally, some comments are in order regarding the limitations of the present study. Perhaps most important, it should be acknowledged that the effect-size of our study was rather small (i.e., $R^2$ = 0.04). Nevertheless, given the relatively small range in substance use in the present sample, together with the methodological limitations of the type of behavioral measure we used (i.e., RT measures such as the

SOT provide only a rough indicator of attentional processes), small effects are noteworthy. The importance of even small effects is underscored by the considerable risk for negative health and social consequences that are associated with substance use behavior. As a further limitation, commonly used measures of substance use problems such as the Rutgers Alcohol Problem Index (RAPI; White & Labouvie, 1989) were not included in TRAILS, although this type of information would have been of supplemental value for the current study. Finally, because of the unbalanced, fixed order of the positive and negative games, it is not possible to draw any conclusion regarding absolute effects. However, because the order was the same for all participants, no problems seem to arise inferring the relative effects of this study.

To conclude, this study was the first to show that heavier-using adolescents were characterized by a generally enhanced attentional engagement toward cues of reward and non-punishment. The pattern of findings is consistent with the hypothesis that such a generally enhanced attentional bias for appetitive cues may set adolescents at risk for developing excessive substance use. An important next step would be to corroborate these findings in a longitudinal design.

# APPENDIX 2A

*Number of participants in the low and high risk profile groups in the total TRAILS population (i.e., pop.) and in the focus cohort of participants who performed laboratory tasks (i.e., focus)*

| | | Boys<br>N | Girls<br>N | Total<br>N |
|---|---|---|---|---|
| Low risk (not A, B or C) | pop. | 462 | 477 | 939 |
| | focus | 119 | 123 | 242 |
| Temp. (A) | pop. | 165 | 138 | 303 |
| | focus | 53 | 56 | 109 |
| Parental psychopathology (B) | pop. | 142 | 175 | 317 |
| | focus | 51 | 52 | 103 |
| Single-parent family (C) | pop. | 79 | 96 | 175 |
| | focus | 28 | 38 | 66 |
| AB | pop. | 72 | 66 | 138 |
| | focus | 33 | 32 | 65 |
| AC | pop. | 41 | 25 | 66 |
| | focus | 13 | 10 | 23 |
| BC | pop. | 76 | 99 | 175 |
| | focus | 31 | 33 | 64 |
| ABC | pop. | 57 | 53 | 110 |
| | focus | 23 | 20 | 43 |
| Total | pop. | 1094 | 1129 | 2223 |
| | focus | 351 | 364 | 715 |

*Note.* The selection criteria for high-risk profile group were as follows:

**High-risk temperament**: EATQ (Early Adolescent Temperament Questionnaire) Frustration ≥ 90$^{th}$ percentile or EATQ Fear ≥ 90$^{th}$ percentile or EATQ Effortful Control ≤ 10$^{th}$ percentile. $N_A$ = 617 (27.8%), 282 girls, 335 boys.

**Parental psychopathology:** at least one parent with severe psychopathology. $N_B$ = 740 (33.3%), 393 girls, 347 boys.

**High environmental risk:** at least one of both biological parents is not part of the family. $N_C$ = 526 (23.7%), 273 girls, 253 boys.

# APPENDIX 2B

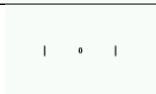
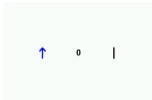
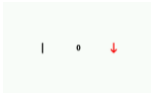
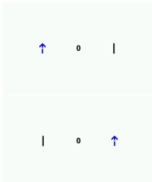
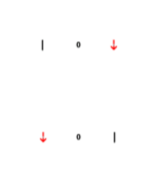
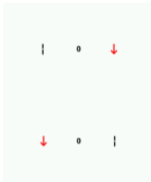
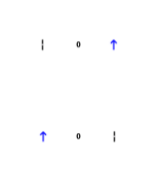
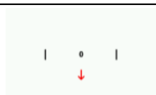
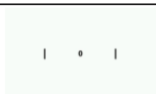
*Overview of the Spatial Orienting Task procedure*

| Spatial Orienting Task | | | | | |
|---|---|---|---|---|---|
| | | N trials | | | |
| Block | Game | Cued | Uncued | Catch | Cut-off RTs |
| 1 | Practice pos. game | 6 | 6 | 2 | Fixed 350ms |
| 2 | Practice neg. game | 6 | 6 | 2 | Fixed 350ms |
| 3 | Positive game | 32 | 16 | 8 | Based on RT block 1 |
| 4 | Positive game | 32 | 16 | 8 | Based on RT block 3 |
| 5 | Negative game | 32 | 16 | 8 | Based on RT block 2 |
| 6 | Negative game | 32 | 16 | 8 | Based on RT block 5 |
| 7 | Positive game | 32 | 16 | 8 | Based on RT block 4 |
| 8 | Positive game | 32 | 16 | 8 | Based on RT block 7 |
| 9 | Negative game | 32 | 16 | 8 | Based on RT block 6 |
| 10 | Negative game | 32 | 16 | 8 | Based on RT block 9 |

*Note.* RT = reaction time; pos. = positive; neg. = negative.

# APPENDIX 2C

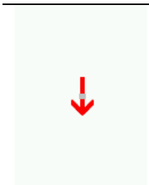
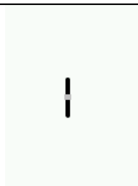
*Schematic overview of trial structure*

| Duration | Trial structure | Composition of sequential screens within one trial | | |
|---|---|---|---|---|
| 200ms | 2 vertical black bars (size 0.16 x 0.64 cm) – mark location of cues and targets |  | | |
| 250ms | Fixation score<br>in between 2 bars (size 0.6 x 0.9 cm per digit) |  | | |
| 250ms (short-delay trial)<br>or<br>500ms (long-delay trial) | Cue arrow (size 0.5 x 1.3 cm, shaft width 0.16 cm) replaces one of the bars | Easy cue - high chance at positive outcome<br><br> | Hard cue – high chance at negative outcome<br><br> | |
| 500 ms after response or 1s when no response | Target (small vertical gray rectangle, 0.08 x 0.24 cm) - press 'b' as fast as possible if you see target (see fig. S1), no target: don't press any button | 2/3 of targets cued – (target easy or hard)<br><br>PRESS B<br><br>Easy condition –<br>much time to react (i.e., own median RT + 0.55 SD)<br><br>Hard condition –<br>little time to react (i.e., own median RT – 0.55 SD)<br> | 1/3 of targets uncued – (target easy or hard)<br><br><br><br> | 1/7 of trials no target<br><br>DON'T PRESS |
| 500ms | Reinstated black bars + feedback signal |  |  | |
| 250 ms | Updated total score |  | | |

*Note:* RT = reaction time.

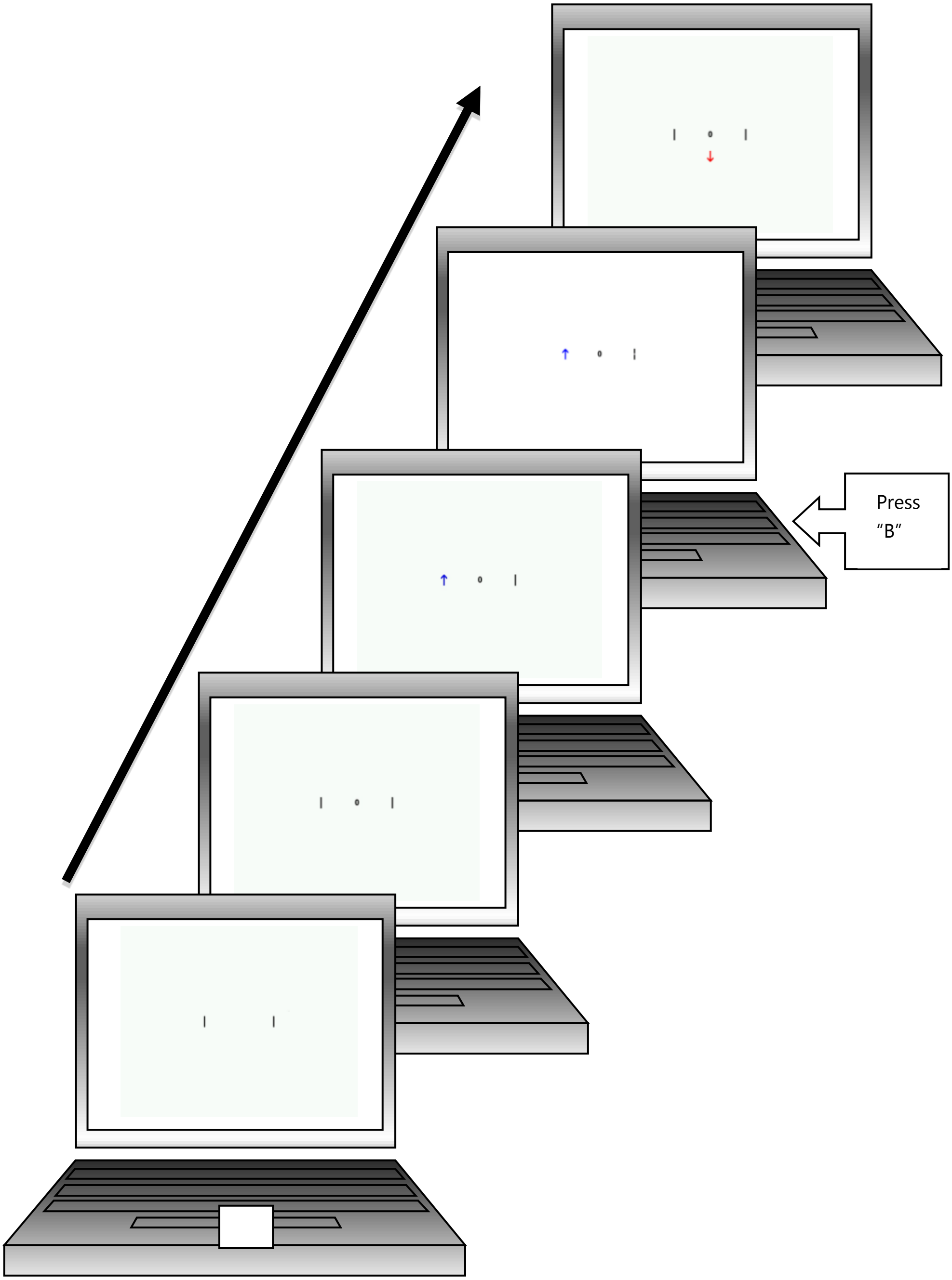
# APPENDIX 2D

*Examples of cued hard target, cued easy target, and uncued target*

| Cued hard target | Cued easy target | Uncued target |
|---|---|---|
|  |  |  |

# APPENDIX 2E

*Example of screen-setup of the Spatial Orienting Task (SOT) - Example of easy cue, followed by a target in the uncued location (i.e., hard target) with subsequent slow response (i.e., negative feedback)*



# APPENDIX 2F

*Items and response categories of self-reported substance use, subdivided by substance (alcohol, tobacco, cannabis)*

| Item | Substance | Question | Response categories |
|---|---|---|---|
| 1 | Alcohol | At how many days did you drink alcohol last week | 0-7 = 0 to 7 days |
| 2 | | How many glasses of alcohol did you drink last week | 0-6 = 0 to 6 glasses, 7 = 7-10 glasses, 8 = 11 or more glasses |
| 3 | | How many times did you drink alcohol in your lifetime? | 1-10 = 1 to 10 times, 11 = 11-19 times, 12 = 20-39 times, 13 = 40 times or more |
| 4 | | How many times did you drink alcohol in the last twelve months? | 1-10 = 1 to 10 times, 11 = 11-19 times, 12 = 20-39 times, 13 = 40 times or more |
| 5 | | How many times did you drink alcohol in the last 4 weeks? | 1-10 = 1 to 10 times, 11 = 11-19 times, 12 = 20-39 times, 13 = 40 times or more |
| 6 | | At how many week days do you normally drink alcohol? | 0-3 = 0 to 3 days |
| 7 | | How many glasses of alcohol do you normally drink at a week day? | 0-6 = 0 to 6 glasses, 7 = 7-10 glasses, 8 = 11 or more glasses per day |
| 8 | | At how many weekend days do you normally drink alcohol? | 0-3 = 0 to 3 days |
| 9 | | How many glasses of alcohol do you normally drink at a weekend day? | 0-6 = 0 to 6 glasses, 7 = 7-10 glasses, 8 = 11 or more glasses per day |
| 10 | Tobacco | Did you ever smoke, even if it was just one cigarette or a few drafts? | 0 = never, 1 = 1 or 2 times, 2 = not every day, 3 = I stopped, 4 = every day |
| 11 | | How many cigarettes do you normally smoke at a smoking day? | Continuous, 0 - ∞ |
| 12 | | How many cigarettes did you smoke in the past week? | 0 = I never smoke, 1 = 0 cigs, 2 = less than 1, 3= 1-5 cigs, 4 = 6-10 cigs, 5 = 11-20, 6 = 20 or more |
| 13 | | How many cigarettes did you smoke in the past four weeks? | 0 = I never smoke, 1 = 0 cigs, 2 = less than 1, 3= 1-5 cigs, 4 = 6-10 cigs, 5 = 11-20, 6 = 20 or more |
| 14 | Cannabis | How many times did you use weed or hash in your lifetime? | 1-10 = 1 to 10 times, 11 = 11-19 times, 12 = 20-39 times, 13 = 40 times or more |
| 15 | | How many times did you use weed or hash in the last twelve months? | 1-10 = 1 to 10 times, 11 = 11-19 times, 12 = 20-39 times, 13 = 40 times or more |
| 16 | | How many times did you use weed or hash in the last four weeks? | 1-10 = 1 to 10 times, 11 = 11-19 times, 12 = 20-39 times, 13 = 40 times or more |